



REDUCTION OF INRUSH CURRENT IN TRANSFORMER BY USING CONTROL SWITCHING AND POWER ELECTRONIC CONVERTER

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Abstract — Transformer is one of the most vital and costlier equipment in power system. When the transformer is energized from a standard power source it draws a very high transient current which is called the inrush current. This magnetizing inrush current causes system disturbances and damages the transformer windings. To improve this situation inrush current is required to be reduced. This paper discusses inrush current limiters that reduce inrush current at the time of switching of the transformer. Here, inrush current limiters using control switching and power electronic converter- voltage source PWM converter are used. Simulations using MATLAB are carried out and results are tabulated.

Keywords- Inrush Current Theory, Control Switching Method, Different Angle Scope output, Use of series connected voltage-source PWM converter, Comparison of Technique

I. INTRODUCTION

During switching on the transformer the maximum value of flux will jump to double of its steady state maximum value. As, after steady state maximum value of flux, the core becomes saturated, the current required to produced rest of flux will be very high. So transformer primary will draw a very high peaky current from the source which is called Energization inrush current in transformer.

The core is used with specify initial fluxes and saturated core. Some amount of flux provide in each phases to get the value of inrush current. When the transformer energized, the flux of all three phases will increase and reached till the maximum value of flux and after that maximum value, the flux will become saturated and draw more current from source, which may be 5 to 10 time greater than rated current.

The main reason of saturation of flux is residual flux. Residual flux is nothing but it is some amount of flux which remains in the transformer core at the time of de-energization of transformer. Residual flux is depending on the rating of transformer and de-energization instant. It will have different value for different rating transformer.

In this paper Control Switching Method and Power Electronic Converter use for mitigation of inrush current.

II. Inrush Current Theory

According to Faraday's law of electromagnetic induction the voltage induced across the winding is given as $e = d\phi/dt$.

Where ϕ is the flux in the core. Hence the flux will be integral of the voltage wave.

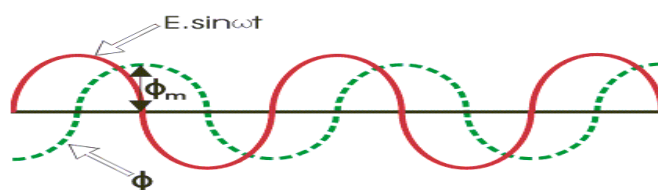


Figure 1. The flux wave is initiated from the same origin as voltage waveform

$$e = E \cdot \sin \omega t = \frac{d\phi}{dt} \Rightarrow \phi = \int e \cdot dt = E \int \sin \omega t \cdot dt$$

If the transformer is switched on at the instant of voltage zero, the flux wave is initiated from the same origin as voltage waveform, the value of flux at the end of first half cycle of the voltage waveform will be

$$\phi_{m'} = (E/\omega) \int_0^{\pi} \sin \omega t \cdot dt = \phi_m \int_0^{\pi} \sin \omega t \cdot d(\omega t) = 2\phi_m$$

Where ϕ_m is the maximum value of steady state flux.

The transformer core are generally saturated just above the maximum steady state value of flux. But in our example, during switching on the transformer the maximum value of flux will jump to double of its steady state maximum value. As, after steady state maximum value of flux, the core becomes saturated, the current required to produced rest of flux will be very high. So transformer primary will draw a very high peaky current from the source which is called magnetizing inrush current in transformer or simply inrush current in transformer.

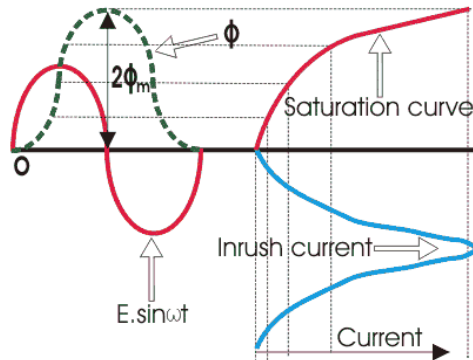


Figure 2. Waveform showing inrush current

Magnetizing inrush current in transformer is the current which is drawn by a transformer at the time of energizing the transformer. This current is transient in nature and exists for few milliseconds. The inrush current may be up to 10 times higher than normal rated current of transformer. Although the magnitude of inrush current is so high but it generally does not create any permanent fault in transformer as it exists for very small time. But still inrush current in power transformer is a problem, because it interferes with the operation of circuits as they have been designed to function. Some effects of high inrush include nuisance fuse or breaker interruptions, as well as arcing and failure of primary circuit components, such as switches. High magnetizing inrush current in transformer also necessitate oversizing of fuses or breakers. Another side effect of high inrush is the injection of noise and distortion back into the mains.

III. Control Switching Method

MATLAB is user friendly software with simpower system toolbox. A test is driven on 250 MVA, 20kV/230kV Saturable Transformer in MATLAB/SIMLINK environment.

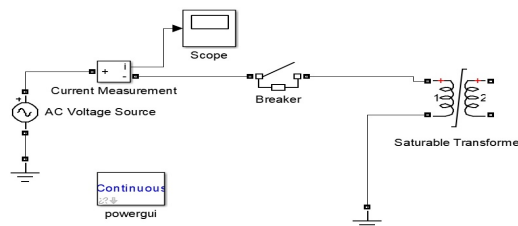


Figure 3. Matlab Model

The switching time of circuit breaker is changed from 0° to 30° , 60° and 90° and various results are observed and analyzed. The calculations for switching angle are given as below-

Time duration for 50 cycles = 1000 msec

1 cycle = 0.02 sec (360 Degree)

For switching Time for Circuit Breaker with $0^\circ, 30^\circ, 60^\circ, 90^\circ$ Angle apart-

$0^\circ=0$ sec , $30^\circ=0.00166$ sec, $60^\circ=0.00333$, $90^\circ=0.005$ sec,

Inrush Current at Different Switching angle waveform bellow

A. Simulation Result at Different angle

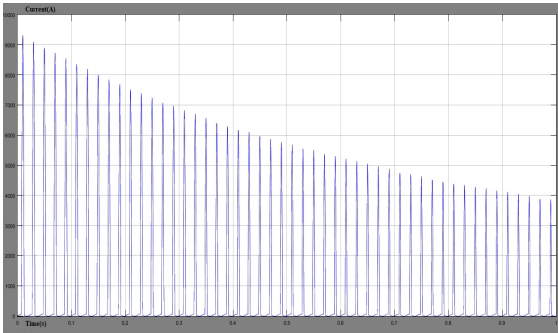


Figure 4. Current waveform at 0°

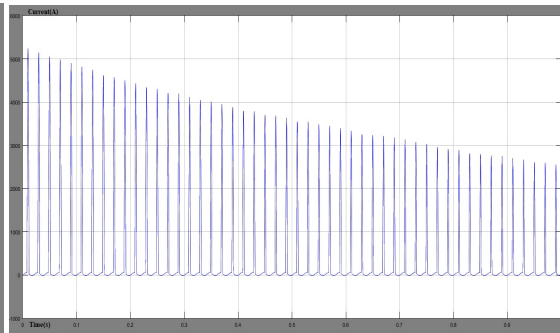


Figure 5. Current waveform at 30°

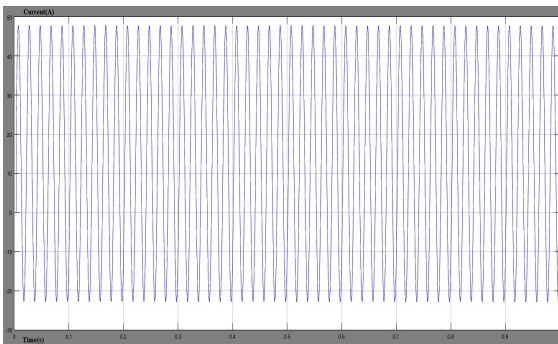


Figure 6. Current waveform at 60°

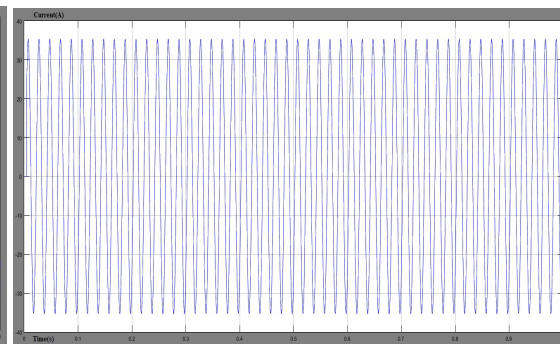


Figure 7. Current waveform at 90°

B. Table (1) of Simulation Output at different angle

Angle	Inrush Current(A)
0°	9307
30°	5237
60°	47
90°	35

It is observed when the transformer is operated at an angle of 90 degree the value of the inrush current was found to be minimal.

IV. Use of series connected voltage-source PWM converter

In this technique, the transformer is connected to the source, while suppressing the inrush current is done by a series connected PWM-converter. The series compensator injects a compensating current on the secondary winding of the series transformer. The compensating current supplied by the series compensator has opposite polarity to that of inrush current produced by the Saturable transformer.

In the proposed circuit shown in Fig. 5, Tr0 is the main transformer causing the inrush current phenomenon. A small-rated voltage-source PWM converter is connected in series between the main transformer Tr0 and the source Vs through a matching transformer Tr1.

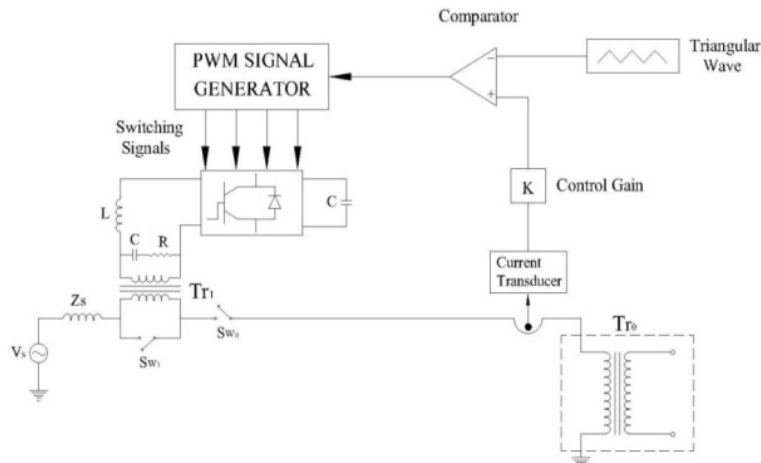


Figure 8. Voltage source PWM converter type inrush current

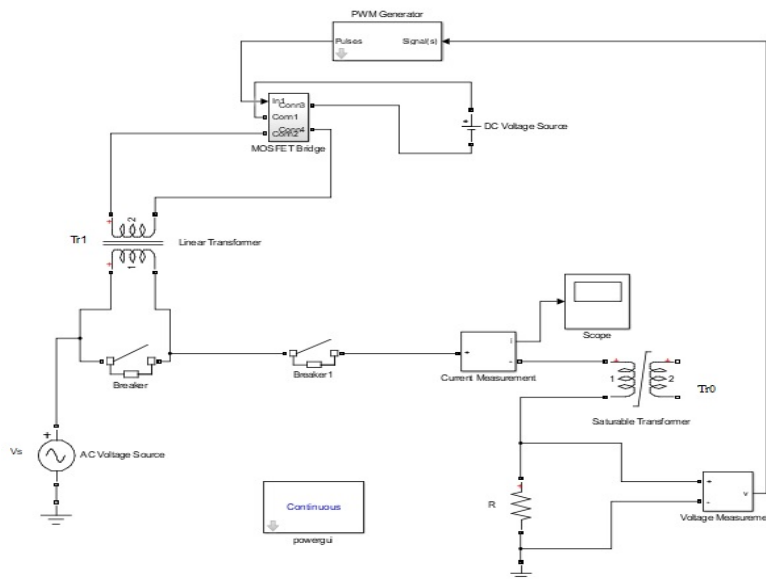


Figure 9. Simulation set up of using series connected voltage source PWM converter

The PWM converter acts as a resistor where the sine-triangle intercept technique is used. This strategy with control reference signal for generate switching signals operated at a resistance of $K[\Omega]$ with respect to the transformer primary current, and the inrush current accompanying the input of the transformer is suppressed. As a result, the inrush current is well suppressed with such a new control approach.

The inrush current that accompanies power flow to the transformer can be suppressed. This method requires no information of the transformer, amount of residual flux, phase angle and so on.

$$v_{out} = k \cdot I_{source}$$

The control gain K must be determined so that a voltage that does not exceed the saturation flux value is not applied to the transformer.

A. Simulation Result



Figure 10. Current waveform after using series connected voltage source PWM converter.

With 20KV primary supply given, keeping secondary open, the inrush current observed is as 9307A as shown in Figure 2 . Using series connected voltage source PWM converter Inrush Current reduced to 15A as shown in Figure 7.

V. CONCLUSIONS

Thus the inrush current phenomenon is investigated on a transformer by using the MATLAB Simulink model. It is seen that the peak value of magnetizing inrush current is very high as compared to the normal magnetizing current and when the transformer was operated at an angle of 90 degree the value of the inrush current was found out to be minimal.

In this paper, techniques using power electronic converters to suppress the transformer inrush Current are studied and verified. Main advantages of these methods are simple power circuit, reliable operation, no information required about residual flux, switching instant, etc. Also the cost of these current limiter is less. From the results obtained main conclusions can be summarized from table shown below.

A. Table (2) Comparative Analysis of Methods Using Power Electronic Converters Used to limit the Transformer Inrush Current.

Technique	Current without Limiter(A)	Current with Limiter(A)
Control Switching Method	9307	35
Series connected voltage-source PWM inverter	9307	15

References

1. Ramsis S. Girgis and Ed G. teNyenhuis, "Characteristics of inrush current of present designs of power transformers" Power Engineering Society General Meeting, 2007, IEEE, pp.I-6
2. Al-Khalifah and Saadany, EF(2006), "Investigation of magnetising inrush current in a single phase transformer", Power Engineering Conference 2006, IEEE Halifax, NS, pp.165-171.
3. Paul C. Y. Ling and Amitava Basak, "Investigation of magnetising inrush current in a single phase transformer" IEEE Transaction on Magnetics, Vol.- 24, No.-6, November 1988, pp. 3217-3222
4. Blume,LF,Camilli,G,Farmham,SB & Peterson. "Transformer Magnetising Inrush Current and Influence on System Operation" AIEE Transactions, Vol.-63, No.-6, pp.366-375
5. F. Fard Ali Asghar, and K. P. Basu, "Reduction of three-phase transformer magnetizing inrush current by use of point on wave switching" IEEE, Student Conference-Nov 2009.
6. Apolonio , A Oliveira, JC,Bronzeado, HS & Vasconcellos, "Transformer Controlled Switching for Minimization of Magnetization Transient Current: Strategy Proposal and Laboratory Validation" IEEE/PES Transmission and Distribution Conference & Exposition :Latin america, pp.505-510
7. Akpınar, S, Coulson, M, Simpson, RR & Slater, RD 1982, 'Calculation of transient current in transformers', IEEE proceedings Generation, Transmission and Distribution, vol. 129, no. 1, pp. 30-34
8. Apolonio, A, Oliveira, JC, Bronzeado, HS & Vasconcellos, AB 2004, 'Transformer controlled switching for minimization of magnetization transient currents: Strategy proposal and laboratory validation', IEEE/PES transmission & distribution conference & exposition: Latin America, pp. 505-510
9. Asrami, MY, Talouki, AY & Mirzaie, M 2012, 'Assessment of inrush current for power transformers by three-dimensional representation', Research journal of applied sciences, engineering and technology, ISSN: 2040-7467
10. Bronzeado, H & Yacamini, R 1995, 'Transformer interection caused by inrush current', *IEEE proceedings on science, measurement and technology*, vol. 142, no. 4, pp. 323-329
11. Chen, SD, Lin, RL & Cheng, CK 2005, 'Magnetizing inrush model of transformers based oh structure parameters', *IEEE transactions on power delivery*, vol. 20, no. 3, pp. 440-443
12. Faiz, J & Saffari, S 2010, 'Inrush current modelling in a single -phase transformer', IEEE transactions on magnetics, vol. 46, no. 2, pp. 578-581
13. Hajivar, GM, Mortazavi, SS & Saniei, M 2010, 'The neutral grounding resistor sizing using an analytical method based on nonlinear transformer model for inrush current mitigation', Universities power engineering conference 2010, 45th international conference, 31Aug – 3 Sep 2010, IEEE, Wales Cardiff
14. Wang, J & Hamilton, R 2004, 'Analysis of transformer inrush current and comparison of harmonic restraint methods in transformer protection', *IEEE*, p. 142-151
15. Xu, W, Absulsalamm S.G, Cui, Y, Chen, S & Liu, X 2005, 'A Sequential Phase Energization Technique for Transformer Inrush Current Reduction - Part II: Theoretical Anaysis and Design Guide', IEEE Transactions on power delivery, vol. 20, no. 2, pp. 950-957
16. Abbas Ketabi and Ali Reza Hadidi Zavareh "New method for inrush current mitigation using series voltage-source PWM converter for three phase transformer" IEEE 2nd Power Electronics, DriveSystems and Technologies Conference 2011, February16-17, 2011, pp. 501-506.
17. Yamada, H., Hiraki, E. and Tanaka T. "A novel method of suppressing the inrush current of transformers using a series-connected voltage-source PWM converter" IEEE International Conference on PEDS 2005, January 16-18, 2006, Vol. 1, pp. 280-285.
18. Mrs. Manisha Wani* (Post Graduate Student) Prof. Kalyani Kurundkar, 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems December16-19, 2012, Bengaluru, India.